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Abstract

THE PROPERTIES OF ZIRCONIUM ALLOYS FOR USE IN WATER COOLED-REACTORS

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Recent work in the United Kingdom on the corrosion, hydriding and mechanical properties of zircaloy-2 and zirconium-2½% niobium alloy is reviewed, with particular emphasis on the use of these materials in pressure-tube reactors.

The resistance to oxidation of the Zr-2½% Nb alloy by pressurised water or steam is slightly inferior to that of zircaloy-2 and is more dependent on its metallurgical condition. Exposure to a high flux of fast neutrons increases the rate of oxidation of both alloys at 300-350°C.

In the SGHWR at Winfrith Heath, the external walls of the pressure tubes may be exposed to moist carbon dioxide containing up to 10 per cent air. Whilst zircaloy-2 is adequately resistant to such exposure, Zr-2½% Nb alloy has extremely high rates of oxidation in some heat treatment conditions.

A particular advantage of the Zr-2½% Nb alloy is that it absorbs less hydrogen than zircaloy-2 during corrosion, whatever the prior heat treatment.

Neither of these alloys would be suitable for use in superheated steam at about 500°C. An investigation aimed at understanding the behaviour of zirconium alloys at this temperature is described briefly.

Experiments with small samples and experience in the manufacture of pressure tubes shows that annealed Zr-2½% Nb alloy has strength comparable to that of cold-worked zircaloy-2, and that higher strength may be achieved by cold-working or heat treatment without serious loss of ductility. Pressure tubes have been

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manufactured from zircaloy-2 with cold-work contents up to 30%, and no greater difficulty has been encountered with 20% cold-worked Zr-2½% Nb alloy despite its increased strength.

The effect of hydrogen on mechanical properties is being investigated. Hydrided material has a higher creep rate than the unhydrided alloys under thermal cycling conditions. The presence of hydrogen in excess of 10 p.p.m. also lowers the energy to failure in impact tests. Preliminary results show that irradiation has the same general effect as hydrogen, lowering the impact energy at any given test temperature. The two effects may be additive for hydrogen contents above about 100 p.p.m.

It is concluded that the use of either alloy as fuel cladding or pressure tubes operating at about 300°C would be technically feasible. The higher strength of the Zr-2½% Nb alloy could be utilised by designing thinner pressure tubes, with a saving in neutron absorption. For a fixed temperature, there is then little difference between the predicted hydrogen contents after a service life of 20-30 years of pressure tubes made from the two alloys: the lower rate of hydrogen absorption of the Zr-2½% Nb alloy would be counterbalanced by the thinner cross-section.